Monetary Policy Under Multiple Financing Constraints *

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Abstract

Firms often face multiple financial constraints. We show theoretically that monetary policy transmits into economic activity in part by influencing which credit constraints are more likely to bind at each point in time. Our model predicts that the more constraints a firm faces, the more muted the response of its borrowing and investment to monetary policy easings but the stronger the response to tightenings, especially if the constraints have very different interest rate sensitivities. We test this implication using US firm microdata and provide evidence in favor of this asymmetric monetary transmission through our novel channel. At the aggregate level, we find, both empirically and in model-based simulations, that our asymmetric monetary transmission channel is quantitatively significant. Moreover, our mechanism can account for a large part of the well-documented, but so far unexplained, asymmetric response of aggregate investment and employment to monetary policy, and can explain slow recoveries from recessions when a large share of firms is financially constrained.

Keywords: Monetary policy, asymmetry, firm heterogeneity, investment, financial frictions

JEL Classification Codes: D22, D25, E22, E44, E52

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1 Introduction

The firm credit channel is an important transmission mechanism of monetary policy (Bernanke and Gertler, 1995; Gertler and Karadi, 2015). Standard theoretical frameworks of the credit channel impose only one type of constraint on firms' access to external finance (Bernanke et al., 1999; Gertler and Karadi, 2011; Bernanke and Gertler, 1989; Christiano et al., 2014). However, firms often must satisfy multiple types of financial constraints, such as collateral, earnings-based, or leverage constraints, amongst other types (Lian and Ma, 2021; Drechsel, 2023; Greenwald, 2019). What are the implications of the simultaneous presence of multiple occasionally binding financial constraints for the transmission of monetary policy? We show theoretically and empirically that monetary policy transmits into economic activity in part by influencing which credit constraints bind. A first-order consequence of this insight is that the multiplicity of constraints is the source of a novel and strongly asymmetric credit channel that can account for a large part of the well-documented—but so far unexplained—asymmetric response of aggregate investment and employment to monetary policy.

We first develop a simple model of firm investment in which firms can be subject to multiple occasionally binding financing constraints, all of which need to be satisfied, and in which the sensitivities of the constraints to the interest rate differ. Changes to interest rates influence how tight each constraint is and, as a result, which constraint is more likely to be the binding one. Following a contractionary monetary policy action, which tightens all constraints but to varying degrees, the constraint that is the most likely to bind is the *most* rate-sensitive one. Conversely, following an easing of monetary policy, which relaxes all constraints but to varying degrees, the constraint that is the most likely to bind is the *least* rate-sensitive one.

This simple framework allows us to draw several implications for the transmission of monetary policy. First, as the *least* rate-sensitive constraint is the one most likely to bind in response to *easing* shocks, financially constrained firms display a muted response to monetary policy easings. Second, as the *most* rate-sensitive constraint is the one most likely to bind in response to *tightening* shocks, financially constrained firms respond strongly to monetary policy tightenings. Combined, these results imply the role of financial constraints is asymmetric for monetary policy easings and tightenings: constraints amplify the effects of tightenings and dampen the effects of loosenings. Moreover, financial constraints can play an important role in the aggregate asymmetric transmission of monetary policy, and potentially explain why monetary policy easings are often ineffective pushing economies out of financial crises, as those are periods when a large share of firms is financially constrained.

Next, we take the testable predictions of this simple model to the data. We collect well-identified monetary policy shocks—i.e., measured using a high-frequency event-study approach around policy decisions and controlling for information about the state of the economy that might be disclosed through the policy action—and decompose these shocks into contractionary and accommodative. This strategy allows us to control for the state-dependent impact of monetary policy, given our interest in sign-dependence, as the policy innovations we use are, by construction, orthogonal to the state of the economy. We exploit cross-sectional heterogeneity in firms' financial constraints and trace their response to monetary policy tightenings and loosenings, respectively. We use firms' distance to default based on Merton (1974) to measure how financially constrained firms are overall—regardless of the number of constraints they face—as firms close to default have been shown to face relatively inelastic debt and equity supply curves and are thus likely constrained (Farre-Mensa and Ljungqvist, 2016). Exploiting cross-sectional heterogeneity across firms allows us to compare firms in each industry-time cell with each other and to rule out time-specific characteristics that are correlated with firms' constraints that could contaminate our results.

We show that financially constrained firms reduce their investment significantly more, on average, in response to contractionary shocks than their unconstrained counterparts. The opposite is the case for expansionary shocks: firms close to their constraint increase investment by less. More specifically, we find that the capital stock of firms that are constrained—defined as those below the 25th percentile of the distance to default distribution—declines, on average, by 3.6% two years after a one standard deviation contractionary monetary policy shock. We estimate a 2.6% decline in the capital stock after the same contractionary shock in the unconstrained group of firms, those above the 25th percentile of distance to default. In response to accommodative monetary policy shocks, investment increases by 1.8% for unconstrained firms, but remains unchanged for constrained firms. In sum, contractionary shocks "pull" financially constrained firms "with a string", while expansionary shocks resemble "pushing financially constrained firms with a string". A similar pattern as the one found for investment is found for employment. Importantly, our results can explain the well-documented asymmetric effects of monetary policy in the macro-econometric literature (Barnichon et al., 2017; Angrist et al., 2018; Debortoli et al., 2020; Jordà et al., 2020; Barnichon et al., 2022).[1]

For any financial constraint channel to be an important driver of these differential responses of investment, firms' debt flows must follow a similar pattern. To assess this, we explore the heterogeneous response of borrowing across firms with a differential degree of ex-ante default probabilities in response to tightening and loosening shocks. The results mirror those of investment: when monetary policy tightens unexpectedly, firms that are ex-ante already close to default strongly reduce their borrowing–suggesting they hit their borrowing constraint–, while the borrowing of safer firms does not respond to contractionary monetary policy. The magnitudes are similar to investment: total debt of firms in distress declines, on average, by about 6% three years after a one standard deviation contractionary monetary policy shock. We again find that, in response to accommodative monetary policy shocks, borrowing does not respond for either distressed or healthy firms. To further confirm that the estimated asymmetry is due to financial factors, we explore whether the effect of monetary policy on the tightness of financial constraints is asymmetric. We find evidence that

[1]We confirm the asymmetric effects of monetary policy in our data: investment, employment, and net corporate debt issuances respond more to interest rate surprise increases than to decreases.

contractionary monetary policy shocks tighten firms' constraints while, in contrast, accommodative monetary policy does not relax firms' constraints sufficiently. Taken together, these results strongly support the role of financial factors in explaining the asymmetric effects of monetary policy–or, in other words, the asymmetry of the credit channel of monetary policy.

These results are consistent with our model's prediction that the credit channel of monetary policy is asymmetric. To further investigate the origin of the financial asymmetry, we turn to the role of multiple financial constraints. We specifically test whether the asymmetric response of firm borrowing and investment to monetary policy shocks is increasing in the number of financial constraints the firm must satisfy.

The interest-rate sensitivity of financial constraints will likely vary across different types of constraints. For instance, consider a market-value collateral constraint and book leverage financial covenant as two examples of financial constraints. In traditional macro-finance models, the tightness of collateral constraints varies strongly with changes in interest rates (Kiyotaki and Moore, 1997). However, constraints are also often enforced through legally binding financial covenants (Lian and Ma, 2021), which are backward-looking in nature; for example, a common debt covenant requires firms not to exceed a certain book leverage ratio based on the latest available financial report. Financial covenants are, therefore, likely to be less affected by changes in interest rates than collateral constraints, which are influenced by forward-looking market prices.

To test the prediction that the more constraints a firm faces, the more muted the response of its borrowing and investment to monetary policy easings but the stronger the response to tightenings, we rely on loan-level and bond-level information on collateral requirements and financial or net worth covenants of debt contracts. Based on this information, we construct a single variable for each firm that captures the average number of financial constraints it faces. We find that firms in the bottom tercile of the number of constraints display the weakest asymmetry associated with financial constraints, while firms in the top tercile of the number of constraints display a degree of asymmetry nearly twice as strong.

The asymmetric effects of monetary policy can occur for various reasons, which are difficult to disentangle in the time-series data. Our empirical estimates allow us to perform a back-of-the-envelope calculation for the contribution of financial constraints to the aggregate asymmetry. Having shown that a large part of the asymmetric effect of constraints is due to the multiplicity of constraints, this indirectly serves as a test of the aggregate importance of our specific channel. Compared to an economy without financial frictions, the effect of a tightening decreases from 3 to 2.5%, and the effect of loosenings increases from 1.5% to 2%. Hence, financial frictions can account for about 32.5 = 17% of the effects of tightenings and subtract 0.5 = 25% from the effect of loosenings. In the aggregate, contractionary monetary policy shocks are two percentage points stronger than accommodative shocks, of which almost half can be attributed to the role of financial constraints.

Our results carry important aggregate implications. The distribution of net worth determines the prevalence of financial constraints and the strength of the asymmetric effects of monetary policy. With a realistic share of firms facing financial constraints, the asymmetric credit channel translates into strong economy-wide asymmetric effects of monetary policy.

The remainder of the paper is structured as follows. Section 2 lays out a simple model of multiple financing constraints. Section 3 explains the data we use and Section 4 describes our empirical strategy. In Section 5 we present our empirical results. Section 6 extends the simple model. Section 7 concludes.

Literature Review Monetary policy tightening shocks tend to transmit more strongly into aggregate spending and employment than easing shocks, as shown in studies using aggregate time series data (Barnichon et al., 2017; Angrist et al., 2018; Debortoli et al., 2020; Jordà et al., 2020; Barnichon et al., 2022).[2] Papers in this literature typically point to two mechanisms to explain this pattern of asymmetry: downward nominal rigidity in prices and wages (Debortoli et al., 2020) and financial factors (Stein, 2014). Some evidence has been provided on the first mechanism (Debortoli et al., 2020), which turns on the idea that when monetary policy tightens, nominal wages do not adjust downward, leading to large declines in output. Instead, when monetary policy loosens, prices and wages rise, mitigating the changes in output. We consider both mechanisms to be complementary. The focus of this paper is on the second mechanism, and we are the first to study such a mechanism formally.

At the same time, studies exploiting cross-sectional variation in firm-level data show that financial frictions significantly affect firms' response to monetary policy, although these studies do not distinguish between the effects of tightening and easing policy actions (Gertler and Gilchrist, 1994; Cloyne et al., 2023; Ottonello and Winberry, 2020). We contribute to these literatures by showing that the differential effects of monetary policy tightening and easing on firm spending dynamics depend on whether firms are distressed, and that this heterogeneity explains the asymmetric effects of monetary policy documented in the macro-econometric literature.

A large empirical literature studies how firms' financial conditions affect their response to monetary policy. Monetary policy rates and credit spreads tend to comove (Gertler and Karadi, 2015; Gilchrist et al., 2015; Caldara and Herbst, 2019), and the comovement is significantly stronger for more financially distressed firms (Anderson and Cesa-Bianchi, 2020; Palazzo and Yamarthy, 2022). The sales, inventory, and debt of small financially distressed firms are more responsive to a monetary policy tightening (Gertler and Gilchrist, 1994; Caglio et al., 2021), perhaps because they have less flexibility to shift toward alternative forms of financing after banks contract their lending supply when monetary policy tightens (Becker and Ivashina, 2014).

The evidence on the role of heterogeneous firm financial conditions on the response of investment is mixed. Some studies show that more financially distressed public firms react less to (expansion-

[2] Tenreyro and Thwaites (2016) shows that US monetary policy is less powerful in recessions.

ary) monetary policy (Ottonello and Winberry, 2020), while others show this is not the case for small private firms (Caglio et al., 2021), for certain sample periods (Lakdawala and Moreland, 2021), and over longer horizons (Jeenas, 2019). Moreover, some authors argue that firm-level measures of financial distress are highly endogenous and capture other factors; for example, the effect of leverage on monetary policy sensitivity disappears when controlling for firm age and dividend-payer status (Cloyne et al., 2023). We contribute to this literature by reexamining this evidence separately for easing and tightening shocks and showing that this decomposition clarifies important controversies in this literature.

The macro-financial literature using firm-level data often uses event-study methodologies around big contractionary credit shocks such as the global financial crisis to trace the impact of financial factors for the employment (Chodorow-Reich, 2014), investment (Almeida et al., 2011), and productivity (Duval et al., 2020). Manaresi and Pierri (2022) show that contractionary firm-level credit availability shocks have negative productivity consequences, but positive credit supply shocks have limited effects. We contribute to this literature by exploiting cross-sectional firm-level variation in financial conditions to assess the role of financial factors in explaining this pattern.

A recent, small literature has focused on the distinction between EBCs and CBCs. Lian and Ma (2021) find that, in the U.S., EBCs are more prevalent among large, old firms and that EBCs are much more common than CBCs. Similar in spirit to our work, Greenwald (2019) explores how the presence of two different constraints (in his case, two types of EBCs) affect the response of economic activity to monetary policy. His focus is on the state-dependence of the relevance of each constraint and on the impact of this state-dependence for the state-dependence of the effectiveness of monetary policy. Finally, Drechsel (2023) argues that macroeconomic models featuring EBCs deliver dynamics that are empirically more relevant than the ones delivered by models featuring CBCs and that models with EBCs, moreover, generate different conclusions about the relative importance of different shocks in explaining macroeconomic dynamics.

2 A Simple Model with Multiple Financing Constraints

Standard models of firm financial constraints tend to deliver either roughly symmetric responses to monetary policy shocks, even if solved nonlinearly, or ambiguous predictions about the sign and magnitude of any asymmetry. A small literature analyzes frameworks that draw a sharp distinction between normal and crisis times and deliver asymmetric responses to very large shocks (e.g., Brunnermeier and Sannikov (2014); Mendoza (2010)). Those frameworks are not suitable for the analysis of monetary policy transmission outside of rare crisis times. A larger literature incorporates permanently binding collateral constraints (e.g., Bernanke et al. (1999) or Ottonello and Winberry (2020)) but for the most part does not study the asymmetric transmission of monetary policy (or other) shocks—as, in fact, most of these models are analyzed by obtaining a log-linear solution around a steady state. The few models that do obtain such an asymmetry, do so under very particular assumptions. For example, in Kiyotaki and Moore (1997), the economy responds asymmetrically to exogenous productivity shocks, somewhat mechanically, because of the assumptions of production function concavity in the sector that prices the collateral asset and of permanently binding collateral constraints that are sensitive to asset prices.

Instead, we introduce a theoretical framework that unambiguously delivers an asymmetric response to monetary policy shocks under one very mild and empirically realistic assumption: the presence of multiple borrowing constraints. The intuition is straightforward: under this assumption, the more rate-sensitive constraints will be more likely to bind after contractionary policy shocks while the less rate-sensitive constraints will be more likely to bind after easing shocks.

In this section, we first introduce the simplest possible model that delivers an asymmetric transmission channel of monetary policy. In Section 6, we extend this simple framework to derive implications for the response of macroeconomic aggregates and to make the model useful for quantitative analysis.

2.1 Environment

Consider an individual firm within a competitive industry that has to decide whether to invest in a capital good $k \geq 0$. This firm lives for only two time periods and at the initial period has a starting endowment of the capital good that has already been preset. The firm operates a production technology with decreasing marginal returns that transforms capital good $k_t \geq 0$ into an output good $y_t \geq 0$ according to

$$y_t = F\left(k_t\right), \tag{1}$$

where subindex $t \in \{0, 1\}$ indicates time and where function $F(\cdot)$ satisfies $F(0) = 0$, $F'(\cdot) > 0$, and $F''(\cdot) < 0$. The capital good depreciates at a constant rate $\delta \geq 0$. Investing in the capital good involves a convex cost of adjusting the stock of capital, which is represented by function $H(|k_1 - k_0|)$, with $H(0) = 0$, $H'(0) = 0$ and $H'(\cdot) \geq 0$, and $H''(\cdot) \geq 0$, where $k_1 - k_0 \in \mathbb{R}$ is investment net of depreciation.

Denote the gross interest rate between the periods by $R \geq 1$ and assume for simplicity a constant price of the capital good normalized to 1. Then, the objective of the firm is to maximize the following present discounted value of profits:

$$\max_{k_1 \geq 0} \left\{ F\left(k_0\right) - \delta k_0 - \left(k_1 - k_0\right) - H\left(|k_1 - k_0|\right) + \frac{1}{R}\left[F\left(k_1\right) - \delta k_1 + k_1\right] \right\}. \tag{2}$$

Assuming disinvesting is not optimal, the unconstrained solution to the problem is $k_1\left(k_0; R\right) \geq k_0$, with

$$1 + H'\left[k_1\left(k_0; R\right) - k_0\right] = \frac{1}{R}\left[F'\left[k_1\left(k_0; R\right)\right] + (1 - \delta)\right]. \tag{3}$$

Define $k_* \equiv k_1(k_*; R) \geq 0$, or equivalently,

$$1 = \frac{1}{R}\left[F'(k_*) + (1-\delta)\right]. \tag{4}$$

To effectively guarantee $k_1(k_0; R) \geq k_0$, in what follows, we assume $k_0 \leq k_*$, which intuitively means that the firm is not willing to disinvest since its initial production scale is not above the efficient one.

Let $\bar{k}_0 \geq 0$ be such that under the unconstrained optimal scale profits are null at the initial period. Formally, $\pi_0\left(\bar{k}_0; R\right) = 0$, with $\pi_0(\cdot; R)$ being given by

$$\pi_0(k_0; R) \equiv F(k_0) - \delta k_0 - [k_1(k_0; R) - k_0] - H[k_1(k_0; R) - k_0]. \tag{5}$$

Then, the firm needs to borrow to invest according to $k_1(k_0; R) - k_0$ if $k_0 < \bar{k}_0$ whereas otherwise it does not. We consider a case in which $\bar{k}_0 < k_*$ to encompass both the possibilities of requiring and of not requiring external financing to optimally invest, that is, $k_0 < \bar{k}_0$ and $k_0 \geq \bar{k}_0$, respectively.

External financing nonetheless is limited and thus the firm may not be able to attain its unconstrained optimal scale. We assume the firm has no initial debt which implies its initial net worth equals k_0. More importantly, in addition, we assume the firm may be subject to a large number (i.e., multiple) financing constraints. For the moment, we remain agnostic about the nature and the number of the constraints, and impose only the following set of conditions over the maximum feasible production scale $G_j(k_0; R) \geq (1-\delta) k_0$ associated with each of them, where $j \in \{1, ..., N\}$ denotes for the individual constraints and $N \geq 1$ is the number of them. First, the maximum feasible scales are increasing in net worth k_0. Second, the scales inversely respond to a change in the interest rate. Third, the scales may feature different sensitivities to the change in the interest rate. Fourth, and lastly, the scales are continuously differentiable in the rate.

The constrained optimal scale is then $\hat{k}_1(k_0; R) \geq (1-\delta) k_0$, with

$$\hat{k}_1(k_0; R) \equiv \min\left\{\min_{j \in \{1,...,N\}} \{G_j(k_0; R)\}, k_1(k_0; R)\right\}. \tag{6}$$

Below we describe the response of gross investment $\hat{k}_1(k_0; R) - (1-\delta) k_0$ to a marginal change in interest rate R. First, we consider the case in which the firm is financially constrained [i.e., $\hat{k}_1(k_0; R) < k_1(k_0; R)$] and then we turn the attention to the case in which the firm is financially unconstrained. In the former case, we assume there exist $k_0 < \bar{k}_0$ and $B(k_0) \subset \{1, ..., N\}$ such that

$$\min_{j \in B(k_0)} \{G_j(k_0; R)\} = \min_{j \in \{1,...,N\}} \{G_j(k_0; R)\} < k_1(k_0; R) \tag{7}$$

with $j \in B(k_0)$ and $j' \in B(k_0)$ for at least two different financing constraints $j \neq j'$. This assumption allows us to consider the subcase with multiple binding financing constraints.

2.2 Investment Responses: Financially Constrained Firm

Proposition 1 (Condition for asymmetry). *If multiple financing constraints are binding, investment responds more aggressively to a marginal increase in the interest rate than to a marginal decrease of equal size. By contrast, if a single constraint is binding, the response is symmetric.*

The proof of the proposition is as follows. If the firm is financially constrained—regardless of the number of binding financing constraints—to a marginal increase in the interest rate investment responds in absolute terms according to

$$\left| \lim_{h \to 0^+} \frac{\hat{k}_1(k_0; R+h) - \hat{k}_1(k_0; R)}{h} \right| = \max_{j \in B(k_0)} \left\{ \left| \frac{\partial}{\partial R} G_j(k_0; R) \right| \right\} . \tag{8}$$

To a marginal fall in the interest rate, the absolute response of investment instead is

$$\left| \lim_{h \to 0^-} \frac{\hat{k}_1(k_0; R+h) - \hat{k}_1(k_0; R)}{h} \right| = \min_{j \in B(k_0)} \left\{ \left| \frac{\partial}{\partial R} G_j(k_0; R) \right| \right\} . \tag{9}$$

These formulae hold because all of the constraints must simultaneously be satisfied always. If multiple constraints are binding, then following a marginal increase in the interest rate, investment contracts according to the binding constraint that tightens by more, whereas following a marginal fall in the interest rate, investment expands according to the binding constraint that relaxes by less. This naturally implies an asymmetric response of investment with respect to the sign of the change in the interest rate. By contrast, if a single constraint is binding, the response of investment is symmetric, because the minimum and the maximum absolute responses coincide.

Proposition 2 (Strength of asymmetry). *If multiple financing constraints are binding—everything else the same—the larger the number of binding financing constraints, the stronger the asymmetry in the response of investment to a marginal change in the interest rate.*

This proposition follows directly from formulae (8) and (9). It holds because, everything else the same, the maximum operator is increasing in the number of its arguments while the minimum operator is decreasing. The proposition naturally implies an intensive margin in the number of binding financing constraints concerning the strength of the asymmetry in the investment response.

2.3 Investment Responses: Financially Unconstrained Firm

Finally we turn the attention to the case in which the firm is financially unconstrained.

Proposition 3 (Strength of unconstrained response). *If no financing constraint is binding, everything else the same, the degree at which marginal adjustment costs increase in net investment dampens the response of investment to a marginal change in the interest rate.*

This proposition directly follows from applying the Implicit Function Theorem to condition (3) to analytically derive the response of $k_1(k_0; R) - (1-\delta) k_0$ to a marginal change in the interest rate. Specifically, from proceeding in such a manner, one obtains

$$\left| \frac{\partial}{\partial R} k_1(k_0; R) \right| = \frac{\frac{1}{R^2} \left[F' \left[k_1(k_0; R) \right] + (1-\delta) \right]}{H'' \left[k_1(k_0; R) - k_0 \right] - \frac{1}{R} F'' \left[k_1(k_0; R) \right]} . \tag{10}$$

This formula directly reveals that everything else the same a higher $H'' [k_1(k_0; R) - k_0]$ dampens $|\partial k_1(k_0; R) / \partial R|$.

2.4 Testable Implications

Taken together these propositions suggest that in an industry with both financially constrained and financially unconstrained firms the following results concerning investment responses to a change in the interest rate hold. First, financially constrained firms as a group—which encompasses both firms with a single and with multiple binding financing constraints—tend to feature more aggressive responses to an increase in the interest rate than what financially unconstrained firms tend to do. Second, the opposite relative aggressiveness tend to hold for a fall in the interest rate. Third, the response of the financially constrained firms tend to be more asymmetric with respect to the sign of the change in the interest rate than the response of the financially unconstrained firms. In a related vein, the propositions also suggest that equivalent results follow when comparing responses across industries that can be ranked in terms of additional classes of binding financing constraints.

Next, we examine U.S. firm microdata to investigate the empirical validity of these results.

3 Data

Our sample consists of U.S. firms covered by Compustat at a quarterly frequency between 1990 and 2021, excluding utilities (Standard Industry Classification (SIC) codes 4900–4949) and financials (SIC codes 6000–6999). We remove observations with negative revenues, missing information on total assets or capital, or a value of total assets under \$10 million in 2012 U.S. dollar value. We winsorize all variables at the 1% level to remove outliers. Firms in the sample are required to be active for at least five years after the monetary policy shock occurs, to cover the length of the horizon of the effects we study and ensure that effects are not driven by firm samples being different at short and long horizons. We refer to investment as the log difference in the capital stock, following Ottonello and Winberry (2020). Employment is not available at a quarterly frequency from Compustat. We use the annual Compustat data and linearly interpolate the employment data to study the effect of quarterly monetary policy shocks on employment.

One of our key firm-level variables is the distance to default, which captures the likelihood of default over the near-term horizon. It is our baseline proxy for financial distress, as it is less likely to be affected by endogeneity concerns (Farre-Mensa and Ljungqvist, 2016). Distance to default is computed using Compustat and CRSP data following the Merton distance to default model, which takes as inputs the firm's equity valuations and leverage.

Our proxies for monetary policy shocks borrow from the work of Miranda-Agrippino and Ricco (2021) and Jarociński and Karadi (2020). These authors follow a well-established literature that uses high-frequency financial market surprises around key monetary policy announcements to identify unexpected variations in monetary policy. The innovative aspect of their approach is that they can separately identify exogenous monetary policy shocks from shocks about new information from the Federal Reserve regarding the state of the economy. These monetary policy shocks are therefore orthogonal to shocks to firms' investment opportunities. We compute the monetary surprise by adding up the monthly monetary policy shocks at the quarterly frequency. We separate the shock series into accommodative and contractionary shocks, which takes the value of the original shock if the shock is negative and positive, respectively, and value 0 otherwise.

For our baseline monetary policy shock, the Miranda-Agrippino and Ricco (2021) on the run 2-year wide surprises, we have 62 contractionary and 56 accommodative shocks. The average size of the contractionary (accommodative) shock is 5 (6) basis points with a standard deviation of 4 (5) and a maximum of 20 (29). We standardize the monetary policy shocks so that one unit is equal to a one standard deviation shock.

4 Empirical Strategy

We provide evidence on how exogenous changes in interest rates, identified with surprise changes in the monetary policy rate, have a different impact on the investment of firms with different degrees of financial constraints. We do so by estimating the path of the cumulative growth rate of the firm-level stock of real capital using the following Jordà (2005) local projection specification as our baseline estimation framework:

$$\begin{aligned}\Delta_h LogK_{i,t+h} = & \underbrace{\beta_1 MP\ Shock_t}_{\text{Aggregate MP loosening}} + \underbrace{\beta_2 MP\ Shock_{t*} Constraint_{i,t}}_{\text{MP loosening constrained}} + \underbrace{\beta_3 MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Aggregate Differential Effect of Tightening}} \\ & + \underbrace{\beta_4 Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Differential Effect of Tightening constrained}} + \mathbf{X}'\gamma + \epsilon_{i,t}\end{aligned} \tag{11}$$

where $\Delta_h \log K_{i,t+h}$ is the change in the log of the real stock of capital K between the end of quarter $t-1$ and the end of quarter $t+h$ and $MP\ Shock_t$ is the monetary surprise in quarter t. $Constraint_{i,t}$ is defined as the proximity to default. $\mathbb{1}Tightening_t$ is a dummy that is positive if $MP\ Shock_t$ is positive and zero otherwise. Our main coefficient of interest is β_4, which measures whether more constrained firms respond differentially to tightening than to a loosening relative to their unconstrained counterparts. A negative coefficient β_4 indicates that constrained firms decrease their investment more to a tightening than they increase their investment to a loosening relative to less constrained counterparts. On its own, the coefficient, however, is not indicative of whether constrained firms respond more to tightenings relative to unconstrained firms. It is possible that constrained firms always respond more, both to tightenings and to loosenings, but the response to tightenings is stronger than that of loosenings. β_2 tests whether monetary policy loosenings increase investment differentially for constrained relative to less constrained firms. $\beta_2 > 0$ implies that a monetary policy loosenings increases investment less for a more constrained firm. To test whether constrained firms respond more to tightenings relative to unconstrained firms, $\beta_2+\beta_4$ needs to be negative. Since all variables are demeaned, β_1 is the effect of monetary policy tightening for the average firm. A negative sign of β_1 indicates that a monetary policy loosening increases investment. β_3 tests whether tightenings have a differential effects than loosenings for the average firm. A negative β_3 implies that tightenings of monetary policy have a stronger negative effect on investment than loosenings have a positive effect on investment for the average firm. The total effect of monetary policy tightenings is therefore given by the sum of $\beta_1+\beta_3$ for the average firm.

5 Results

5.1 Baseline Results

We start by estimating Equation 11 for $h = 8$ to evaluate the effect of monetary policy two years out. Note that in this equation we are interested in the difference in the response between firms that are more constrained relative to those that are less constrained. $MP\ Shock_t$ is the Miranda-Agrippino and Ricco (2021) monetary policy shock, reflecting positive values for contractionary shocks and negative values for accommodative shocks. $Constrained_{i,t}$ is the demeaned negative value of distance to default, where higher values reflect being more constrained, with a mean of zero. $Contr_t$ is a dummy that takes the value 1 if the shock is contractionary and 0 if it is accommodative. The vector $\mathbf{X}$ includes variables such as the uninteracted regressors, double interactions including aggregated controls interacted with constrained as well as various fixed effects, but we vary $\mathbf{X}$ depending on the specification.

Column (1) reports a specification with only firm fixed effect to control for time-invariant observable and unobservable firm characteristics. The coefficient β_4 is our main coefficient of interest. It tests whether, in response to contractionary monetary policy shocks, firms that are more constrained react more relative to less constrained firms, relative to their response to accommodative shocks. In Table 1 we report that this is indeed the case. The remaining coefficients are also of interest. First, given that our measure of $Constrained_{i,t}$ is demeaned in this specification, the coefficient β_1 on $MP\ Shock_t$ can be interpreted as the effect of the monetary policy action if it is accommodative. The negative and significant estimate indicates that the effect is negative, meaning that monetary policy easing ($MP\ Shock_t < 0$) increases investment. The coefficient β_2 tests whether easing shocks are transmitted more strongly into higher investment for firms that are more constrained. The positive coefficient suggests this. A more accommodative shock ($Shock < 0$) for firms that are more constrained decreases the response to the easing shock. This finding is consistent with Ottonello and Winberry (2020), who document that financially constrained firms respond less than financially unconstrained firms. The difference between $\beta_2 < 0$ and the Ottonello and Winberry (2020) result is that, in our context, we only find the stronger response of less constrained firms for accommodative shocks but not for contractionary ones.

The estimate of β_3 tests the hypothesis of whether, for the average firm, contractionary shocks have stronger effects than accommodative shocks. The negative interaction coefficient indicates that this hypothesis cannot be rejected. Lastly, and as described above, the triple interaction is negative and statistically significant, indicating that, in response to contractionary shocks, firms that are more constrained respond more, *relative* to their response to accommodative shocks. This negative coefficient, however, does not indicate whether firms that are riskier respond more strongly than their less constrained counterparts. For this, we need to test whether the sum of β_2 and β_4 is positive and statistically different from zero. The last row of Table 1 reports the p-value for a t-test for, $\beta_4 + \beta_2 = 0$ and shows that the hypothesis that the sum is equal to zero can be rejected at the 5% level. Overall, this result shows that firms that are more constrained respond more to monetary policy contractions and less to monetary policy easings.

When making the cross-sectional comparison instead of focusing on the time series component, the inclusion of time-fixed effects is possible. In the previous specification, we could not include time-fixed effects because we estimated the effect of the monetary policy shock on investment separately. Column (2) includes time-fixed effects in the specification to control for time-specific characteristics, such as GDP growth, inflation, and aggregate uncertainty that could bias the result. Column (3) additionally saturates the specification with industry-quarter fixed effect to account for sector-specific cyclicality. Lastly, column (4) includes $industry \times time$ fixed effect, which controls not only for aggregate time series but also for time-variant sector-specific characteristics, such as the average investment in the sector in a given period, and only exploits the heterogeneity across firms with differential degrees of constraints at a given point in time. Note that when including these fixed effects, $MP\ Shock_t$ and $MP\ Shock_t \times Contr_t$ are collinear with the fixed effects so that the coefficients cannot be interpreted anymore in columns (2)-(4).

Next, we estimate Equation 11 for every quarter after the monetary policy shock to test for the dynamic effects of monetary policy. Figure 1(a) plots the coefficient of the triple interaction β_4. The coefficient is negative and statistically significant across time. Figure 1(b) plots the coefficient β_2, which is the effect of financial constraints for easing shocks. Instead, the coefficient is positive and significant. These two results show that financial constraints weaken the positive effect of accommodative monetary policy and strengthen the negative effects of monetary policy. Figure 1(c) plots the sum of the two coefficients, which is negative, indicating that for contractionary shocks firms with tighter constraints reduce investment more than firms with looser constraints.

To evaluate the impact for firms that are financially constrained vs. those that are not financially constrained, we use our coefficient estimates of Equation 11 and plug in respective values for the size of the monetary policy shock, a dummy of whether it is a tightening or a loosening shock, and values for financially constrained vs. financially unconstrained firms. We define firms that are financially constrained as those that are at the 75th percentile of the constraint, and those that are financially unconstrained as the 25th percentile of the constraint. We choose a monetary policy shock size of one standard deviation and differentiate between loosening and tightening for financially constrained and financially unconstrained firms, delivering four graphs.

Figure 2 shows a large degree of heterogeneity of their investment response in response to tighter monetary policy across firms that are close and far away from default. Firms that are constrained, see Figure 2(a), reduce their investment in response to a tighter monetary policy stance in a statistically significant way, while firms that are financially unconstrained reduce their investment less, see Figure 2(b). Economically, a one standard deviation tightening shock is associated with an around 4% lower capital stock after two years for firms that are financially constrained relative to a counterfactual in which monetary policy would not have tightened, while the effect on the capital stock of firms that are financially unconstrained is less than 3%. The bottom panel shows the effect of monetary policy loosenings. A one standard deviation monetary policy loosening (a negative shock) increases investment for financially unconstrained firms by around 2%, see Figure 2(d). In contrast, when focusing on the firms that are financially constrained we do not detect a significant impact of monetary policy loosening on investment, see Figure 2(c).

The fact that contractionary shocks lead to a decline in investment for both constrained and unconstrained firms, while a monetary policy loosening only increases investment for financially unconstrained firms, suggests that the overall effect of monetary policy tightenings is stronger than that of monetary policy easings.

In fact, when we plot the response of tightenings and loosenins for the average firm, we see that monetary policy tightening shocks have stronger effects on investment in our sample, confirming the earlier results in the literature. Figure 3 displays the estimate of the average dynamic response of investment to a one standard deviation surprise increase in the interest rate across all firms in our sample using the monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021). The left panel reports the effect of contractionary shocks and shows that they generate a strong and statistically significant drop in investment: a one standard-deviation surprise increase in interest rates is associated with a cumulative drop in investment of about 3 percent of the initial capital stock after 2 years. The right panel, instead, reports the effect of expansionary shocks and shows that investment only increases by 1.25%. in response to a one standard deviation shock.[3]

How much of the aggregate asymmetry is driven by financial constraints? To make this back-

[3] In unreported results, we show that this evidence is robust to considering alternative monetary policy shocks such as Jarociński and Karadi (2020)

of-the-envelope calculation, we can use Equation 11 and compute a counterfactual response of tightening shocks if all firms were unconstrained and compare the counterfactual to the effect of monetary policy tightenings that we observe in the data. Figure 4 shows the results. For tightening shocks even the financially unconstrained firms (blue bars) reduce investment, but financial constraints add to the negative effect of tightenings on investment (red bars). At 8 quarters the contribution of financial constraints to the aggregate tightening is $\frac{3-2.5}{3} = 17\%$. Figure 4(b) shows the same results for loosenings. The blue bars show a strong response of investment to loosening shocks. The red bars are positive, implying that financial constraints subtract from the positive effect of loosening monetary policy on investment, as financially constrained firms do not respond much to monetary policy loosenings. If there were no financially constrained firms, monetary policy loosenings would be $\frac{0.5}{2} = 25\%$ stronger. Figure 4(c) shows the aggregate asymmetry. With the actual share of constrained firms, the aggregate asymmetry is negative, meaning that overall tightening effects are stronger than the effect of loosening. Since financial constraints weaken the effect of loosenings and strengthen the effect of tightenings, the contribution of financial constraints to the aggregate asymmetry is the sum of the contributions: Financial constraints contribute half to the aggregate asymmetry, while the other half is due to other factors, which could include forces such as downward nominal wage rigidities, as proposed by Debortoli et al. (2020).

5.2 Employment

In this subsection, we study the asymmetric effects of monetary policy through financial constraints on employment.Equation 3 replicates Table 1 for employment instead of capital. The estimated specification is analogous to Equation 11 and tests formally whether the effect is different between contractionary and accommodative monetary policy shocks for firms that are more constrained. In the first column, we see again that monetary policy accommodation is associated with an increase in employment. The interaction between the shock and the contractionary monetary policy shock dummy tests whether the effect of monetary policy is stronger for contractions than for easings. We can see that accommodative monetary policy shocks are less effective in stimulating employment than contractionary monetary policy shocks are in curtailing employment, shown by $\mathit{MP\ Shock} \times \mathit{Tightening} < 0$. Across all columns and consistent with the previous results, this effect becomes even stronger when firms are more constrained. Column (2)-(4) further saturate the specification with additional fixed effects and confirm the result.

Overall, this result suggests that monetary policy, as for investment, monetary policy is successful in reducing the workforce due to the credit channel of monetary policy by tightening firms' constraints. However, monetary policy is less effective in increasing employment with accommodative monetary policy, as financially constrained firms are unable to increase their workforce.

5.3 Borrowing

When monetary policy is being loosened unexpectedly, one would expect firms to increase their borrowing due to the lower interest rates and increase their investment.

However, so far, our results suggest that accommodative shocks do not seem to translate into higher investment for firms that are financially constrained. These results suggest that a more accommodative monetary policy stance is unlikely to enable constrained firms to borrow more to invest.

In Table 2 we test this proposition. Firms that are financially constrained reduce their borrowing significantly in response to a surprise tightening of monetary policy. When the monetary policy stance becomes more contractionary, firms that are constrained face a tighter borrowing constraint and are, therefore, unable to keep borrowing. In terms of economic magnitudes, after two years, a one standard deviation tightening shock reduces the debt of firms that are financially constrained by around 5%, while the same shock reduces the debt of firms that are far financially unconstrained by around 2.5%.

5.4 Channel

Monetary policy affects access to external financing. Monetary policy loosening is supposed to loosen the financial constraints of firms and make access to finance easier. Contractionary monetary policy tightens financial constraints and reduces access to external financing. To test whether there is an asymmetry between the effect of monetary policy tightenings and loosenings in affecting financial constraints, we use our measure of constraints and regress its change on monetary policy easings and tightening shocks, respectively. Figure 5 shows a binned scatter plot between monetary policy shocks and our measure of constraints and a linear fit between those two, allowing for a differential fit between stress and contractionary and accommodative monetary policy shocks. For contractionary monetary policy shocks (right of the vertical dotted line at 0) there is a strong positive relationship between the strength of the tightening shock and to what extent constraints tighten. The linear fit between the size of the shock and the constraint is flat for accommodative shocks. Accommodative monetary policy shocks are ineffective in reducing firms' constraint and hence improve their access to financing.

5.5 Evidence of Our Proposed Mechanism

In this section, we provide evidence in support of our main theoretical prediction in Section 2: the asymmetric response of firm borrowing and investment to monetary policy shocks is increasing in the number of financial constraints the firm has to satisfy, as long as the tightness of these financial constraints has different interest rate sensitivities.

To test this prediction, we rely on data from DealScan, which provides detailed information on bank loan originations and includes information on whether the loans are secured and on whether the loans feature financial or net worth covenants. Our simplest approach consists in constructing a single variable for each firm that captures the average number of financial constraints it faces. All firms are, by default, assumed to be subject to earnings-based constraints (which might or might not be binding). All bond-financed firms are assumed to only be subject to earnings-based constraints, in line with the evidence in Lian and Ma (2021). For those firms that are featured in the DealScan dataset, we compute their number of constraints by considering each financial or net worth covenant as one constraint and by adding one constraint if the loan is secured. We compute firm-level averages of the number of constraints over all loans originated to each firm in our sample.

We divide firms into terciles of number of constraints and rerun regression (11) separately for each tercile. The theoretical prediction from the model in Section 2 is that the monetary policy asymmetry introduced by financial constraints is stronger the larger the number of financial constraints a firm has to satisfy. Results are in Table 4 and confirm our theoretical prediction. Firms in the bottom tercile of the number of constraints (which average about 1 constraint) display the weakest asymmetry associated with financial constraints (-0.29***). Firms in the middle tercile of the number of constraints (which average about 2.5 constraints) display a stronger asymmetry (-0.34***) and firms in the top tercile of the number of constraints (an average of four different constraints) display the strongest asymmetry (-0.48***). In sum, a larger number of financial constraints increases the asymmetry of the effects of monetary policy on investment significantly, consistent with our theoretical prediction.

6 Towards A Quantitative Model for the Asymmetric Transmission Channel of Monetary Policy

Despite being highly illustrative, the simple model in Section 2 is not sufficiently rich to derive implications for the response of macroeconomic aggregates. Neither is the model useful for quantitative analysis. In what follows, we extend the model to accommodate those two limitations.

6.1 Environment

Consider a closed economy populated by a standard representative household and a continuum of competitive entrepreneurs of unit size. The household has linear preferences over consumption of a final good, which implies that in a competitive equilibrium, the real interest rate is pin down by her subjective discount factor. From now on, therefore, we denote the real gross interest rate by $R_t \geq 0$, which is exogenous, but allowed to vary over time $t \in \{0, 1, 2, ...\}$.

Entrepreneurs operate a production technology with decreasing marginal returns that transforms physical capital at the current period into the final good at the next one according to

$$y_{t+1} = k_t^{\alpha} \, , \tag{12}$$

where $k_t \geq 0$ is physical capital, $y_t \geq 0$ is the final good, and $\alpha \in (0,1)$ indicates the returns of scale of the technology. Physical capital fully depreciates after one period but there is an investment technology that in the same period transforms the final good into physical capital at a unitary return. Thus, letting $k_{*,t} \geq 0$ denote the unconstrained optimal scale, one gets that the scale is determined as follows

$$\alpha k_{*,t}^{\alpha-1} = R_t \Leftrightarrow k_{*,t} = \left(\frac{\alpha}{R_t}\right)^{\frac{1}{1-\alpha}} . \tag{13}$$

As a remark, note that, everything else fixed, the unconstrained optimal scale is inversely related to real interest rate R_t.

Entrepreneurs may not operate at the unconstrained optimal scale, nonetheless, because they are subject to financing constraints. We assume both a collateral- and an earnings-based type of constraint. The collateral constraint limits debt $b_t \geq 0$ by holdings of physical capital according to

$$b_t \leq \lambda k_t , \tag{14}$$

where parameter $\lambda \in [0,1]$ is interpreted as the fraction of collateralized capital. The earnings constraint instead does so by the present discounted value of the future output, according to

$$b_t \leq \gamma \frac{1}{R_t} y_{t+1} , \tag{15}$$

where parameter $\gamma \in [0,1]$ is interpreted as the share of pledgeable output. We assume both constraints must be satisfied to align the incentives of entrepreneurs with those of debt holders. Thus, capital holdings are effectively restricted by

$$k_t \leq \min\left\{\frac{1}{1-\lambda} n_t, k_{e,t}(n_t)\right\} , \tag{16}$$

where $n_t \geq 0$ is net worth and $k_{e,t}(n_t) \geq n_t$ is implicitly determined as follows[4]

$$k_{e,t}(n_t) - \gamma \frac{1}{R_t} \left[k_{e,t}(n_t)\right]^{\alpha} = n_t , \tag{17}$$

The micro-foundation behind these constraints is as follows. At any time period, entrepreneurs can declare in bankruptcy and, in principle, walk away with their assets and their license to operate the production technology without repaying their debt. However, if they do so, debt holders can attempt to seize the assets or the license as well as can accept a final renegotiation offered by entrepreneurs to resolve their dispute. If during the renegotiation entrepreneurs do not lock the capital into the technology, the holders can subsequently seize a fraction $\lambda \in [0,1]$ of it and sell it in the market. If instead entrepreneurs lock it in, debt holders cannot seize or adjust the capital anymore, but nonetheless can seize the license to operate the technology and subsequently

[4]Effective financing constraint (16) follows from combining constraints (14) and (15) with budget constraint $k_t + b_t = n_t$.

extract a fraction $\gamma \in [0, 1]$ of the generated output. Upon bankruptcy declaration and the resulting renegotiation process, entrepreneurs will thus only offer the minimum of the two possible values associated with the seizes, which from an ex ante perspective gives rise to effective financing constraint (16).[5]

The constrained optimal capital scale is then given by $k_{o,t}(n_t) \geq 0$, with

$$k_{o,t}(n_t) = \min\left\{\frac{1}{1-\lambda}n_t, k_{e,t}(n_t), k_{*,t}\right\}. \tag{18}$$

Decreasing marginal returns in the production technology implies that there exists a net worth level $n_{**,t} > 0$, with

$$n_{**,t} \equiv (1-\lambda)\left(\frac{\gamma}{\lambda}\frac{1}{R_t}\right)^{\frac{1}{1-\alpha}}, \tag{19}$$

such that the following holds:

$$k_{e,t}(n) \begin{bmatrix} > \frac{1}{1-\lambda}n & \text{if } n < n_{**,t} \\ = k_{**,t} \equiv \left(\frac{\gamma}{\lambda}\frac{1}{R_t}\right)^{\frac{1}{1-\alpha}} & \text{if } n = n_{**,t} \\ < \frac{1}{1-\lambda}n & \text{if } n > n_{**,t} \end{bmatrix}. \tag{20}$$

As shown by Figure 6, then lowly capitalized producers are financially constrained by the collateral-based limit, average capitalized producers are instead constrained by the earnings-based limit, and highly capitalized producers are financially unconstrained. Put differently, small producers (i.e., those with a small scale) are collateral-based constrained, midsize producers are earning-based constrained, and large producers are unconstrained. The distance of the constrained capital holding to the unconstrained optimal scale indeed provides a natural measure of the degree of financially constraint.

The capital holdings of entrepreneurs naturally influence the dynamics and the distribution of their net worth. To obtain a competitive equilibrium with both financially constrained and financially unconstrained entrepreneurs, we assume the following dividend payout rule and individual life cycle.

During their lifetime, entrepreneurs distribute dividends to the household, only when they expect the marginal return on their net worth not to exceed a given excess return $\phi \geq 0$ over the interest rate going forward. Formally, entrepreneurs stop accumulating net worth and start distributing dividends when their net worth reaches level $n_{\phi,t} > 0$, with

$$n_{\phi,t} \equiv \min\left\{n \geq 0 : \left[\alpha\left[k_{o,s}(n)\right]^{\alpha-1} - R_s\right] k'_{o,s}(n) \leq \phi \ \forall s \geq t\right\}. \tag{21}$$

[5] Drechsel (2023) provides a comprehensive review of the typical micro-foundations used for rationalizing earning-based financing constraints. The micro-foundation in this paper is consistent with the one adopted by Drechsel (2023).

As an example, if $\phi = 0$ and $R_t = R$ is constant, then $n_{\phi,t} = n_*$ is determined by

$$\min\left\{\frac{1}{1-\lambda}n_*, k_e\left(n_*\right)\right\} = k_* \ , \tag{22}$$

since in this case, as shown by Figure 6, entrepreneurs cannot anymore accrue positive excess returns once they attain the unconstrained optimal scale. Parameter ϕ is interpreted as an additional excess return tied to an outside and off-balance sheet investment opportunity in parallel available to entrepreneurs. For convenience, we assume there are two types of entrepreneurs, one with $\phi = 0$ and the other one with a positive $\phi > 0$ such that

$$\phi \in \left[\frac{\alpha\frac{\lambda}{\gamma}-1}{1-\alpha\lambda}R, \frac{\alpha\frac{\lambda}{\gamma}-1}{1-\lambda}R\right] \ , \tag{23}$$

where $R \geq 0$ is the interest rate in steady state (i.e., the stationary competitive equilibrium). Condition (23) states that in steady state—as well as around neighborhood of it—entrepreneurs with high-return outside opportunities stop accumulating net worth once their collateral-based constraint becomes slack and their earnings-based constraint becomes binding. Formally, at point $n = n_{**}$. At that juncture, their marginal excess return on net worth falls in a discrete manner, as shown by Figure Figure 6, since the earnings-based constraint reduces leverage on the marginal unit of net worth by more than what the collateral-based constraint does. Note indeed that $k_e'\left(n_{**}\right) = \left(1-\alpha\lambda\right)^{-1} < \left(1-\lambda\right)^{-1}$.[6] In what follows, we parameterize the population share of entrepreneurs with low-return outside opportunities with $\beta \in (0,1)$.

Regarding the life cycle, we assume entrepreneurs retire stochastically, according to idiosyncratic process with common probability $\theta \in (0,1)$. Retired entrepreneurs transfer their net worth to the household and immediately afterward are replaced by identical newcomers who receive a share $\varphi \in (0,1)$ of their aggregate produced output as initial endowment. At any time period, therefore, the population density of entrepreneurs with age $a \geq 0$ is $p_a \in (0,1)$, with

$$p_a = \theta\left(1-\theta\right)^a \ , \tag{24}$$

and the initial endowment of each of newcomer is $n_{0,t} = \varphi Y_t$, where $Y_t \geq 0$ is aggregate output.

A competitive equilibrium is a path for aggregate output such that given the path of the interest rate the following condition holds:

$$Y_t = \sum_{a=0}^{+\infty}\theta\left(1-\theta\right)^a\left[\beta\left[k_{o,t}\left(n_{L,a,t}\right)\right]^\alpha + \left(1-\beta\right)\left[k_{o,t}\left(n_{H,a,t}\right)\right]^\alpha\right] \ , \tag{25}$$

[6]Condition (23) is derived by evaluating marginal excess return $\left[\alpha\left[k_c\left(n\right)\right]^{\alpha-1} - R\right]k_c'\left(n\right)$ at $n = n_{**}$. The interval in the condition has positive length because $k_c'\left(n\right)$ is discontinuous at that point. To derive $k_c'\left(n_{**}^+\right)$ we apply the Implicit Function Theorem on (17).

where net worth $n_{j,a,t} \geq 0$ evolved in the past over $s \in [t-a, t-1]$ according to

$$n_{j,a+s-t+1,s+1} = \min\left\{\left[k_{o,s}\left(n_{j,a+s-t,s}\right)\right]^{\alpha} + R_s\left[n_{j,s-t,s} - k_{o,s}\left(n_{j,a+s-t,s}\right)\right], \bar{n}_{j,t}\right\}, \tag{26}$$

with initial condition $n_{j,0,t-a} = \varphi Y_{t-a}$, boundary conditions $\bar{n}_{L,t} = n_{*,t}$ and $\bar{n}_{H,t} = n_{**,t}$, and with subscript $j \in \{L, H\}$ respectively denoting the type of entrepreneur with low- and high-return outside opportunity.

6.2 Steady State

Before studying impulse responses to shocks to the interest rate, we illustrate the dynamics and the distribution of net worth by considering a stationary economy with a constant interest rate, $R_t = R$. Put simply, the steady state. As it is common practice, in this subsection, we omit time subscript t. To guarantee $k_o\left(\varphi k_*^{\alpha}\right) < k_*$ in steady state, and hence also the existence of financially constrained entrepreneurs, we impose the following condition on parameters:

$$\varphi < \min\left\{(1-\lambda)\frac{\alpha}{R}, \frac{\alpha-\gamma}{R}\right\}. \tag{27}$$

In steady state, the net worth of entrepreneurs with age $a \geq 1$ can be recursively computed as follows

$$n_{j,a} = \min\left\{\left[k_o\left(n_{j,a-1}\right)\right]^{\alpha} + R_s\left[n_{j,a-1} - k_o\left(n_{j,a-1}\right)\right], \bar{n}_j\right\}, \tag{28}$$

with initial condition $n_0 = \varphi Y$ and boundary conditions $\bar{n}_L = n_*$ and $\bar{n}_H = n_{**}$. Figure 7 displays the aggregate distribution of the net worth. Under the parameter values under consideration, this distribution only has positive mass at points $n = \varphi Y$, $n = n_{**}$, and $n = n_*$, which implies that a significant share of entrepreneurs operates at the scale at which the two constraints intersect.[7] The distribution is naturally shaped by the dynamics of individual net worth. These dynamics can be summarized as follows.

A starting entrepreneur initially accumulates net worth relatively fast because both her marginal return on capital investments and her leverage are relatively high and because she does not distribute dividends. The entrepreneur continues accumulating net worth and growing her production scale at a relatively fast pace until she reaches the net worth level at which the collateral- and earnings-based constraints intersect. At that juncture, if the entrepreneur has a high return on outside opportunities, she distributes dividends and stops accumulating net worth and growing her scale. By contrast, if she has a low return, the entrepreneur continues behaving as before reaching the juncture, with the key difference that from that point on, she accumulates net worth and grows her scale relatively slow because both her marginal return on capital investments and her leverage are relatively low. This entrepreneur continues with that behavior until eventually she attains the

[7] This result is indeed robust to a distribution of marginal returns on outside opportunities continuous over interval (23).

unconstrained optimal scale, at which point she cannot obtain a higher marginal return than in credit markets, and thus starts distributing dividends and stops accumulating net worth. Regardless of the stage in these dynamics, the entrepreneur retires when it is hit by the retirement shock, at which point a newcomer re-starts them.

6.3 Asymmetric Responses to Shocks to the Interest Rate

We are now ready to study impulse responses to shocks to the interest rate. To do so, we consider a stationary economy that initially is in steady state, until at time t_0, it is hit by an unanticipated shock $\varepsilon \in \mathrm{R}$ to the interest rate. The shock has no persistence which implies that the path of the interest rate is as follows:

$$R_t = \left[\begin{array}{ll} R + \varepsilon & \text{for } t = t_0 \\ R & \text{for } t \geq t_0 + 1 \end{array} \right. . \tag{29}$$

We consider both a negative and a positive shock of equal size. These shocks are set sufficiently small not to induce entrepreneurs with high-return outside opportunities to continue accumulating net worth at point $n = n_{**,t}$.

On impact, the change in the interest rate only affects the unconstrained optimal scale and the maximum possible scale consistent with the earnings-based constraint. That is, $k_{*,t}$ and $k_{e,t}(n_t)$. Both scales inversely respond to the change in the rate. Over the subsequent dynamics, by contrast, the distribution of net worth and the aggregate capital stock do respond to the change in the interest rate. Those two objects are affected with some delay by the previously chosen capital holdings. Moreover, the distribution of net worth is also affected by the capital stock itself (since it determines the initial endowment of newcomers) and by the change on funding costs.

Figure 8 displays impulse responses of capital holdings both at the entrepreneur and the aggregate level for both the negative and the positive shock. On impact, collateral-based constrained entrepreneurs (i.e., those with $n = \varphi Y$) do not respond to either shock while both earnings-based constrained ($n = n_{**}$) and financially unconstrained entrepreneurs ($n = n_*$) tend to respond more aggressively to the positive (i.e., an increase in the interest rate) than to the negative shock (a decline in the rate). The earnings-based constrained respond in such a manner because their collateral-based constraint becomes binding when the interest rate falls whereas their earnings-based constraint remains the binding one when the interest rate increases. The financially unconstrained do so instead because only when the interest rate falls the earnings-based constraint prevents them from attaining the new unconstrained optimal scale. Note that no entrepreneur has idle borrowing capacity in steady state and that financing constraints do not limit reductions in borrowing. Over the subsequent dynamics, these asymmetries naturally shape the more aggressive response of the aggregate capital stock to the increase in the interest rate.

7 Conclusion

In this paper, we have shown empirical support for the hypothesis that financial frictions in nonfinancial firms are important to explain why the magnitude of the response of investment to monetary policy tightening shocks is stronger than the response to easing shocks.

Our results carry an important policy implication, which is that the effectiveness of monetary policy depends on the aggregate distribution of financial conditions in nonfinancial firms. A contractionary monetary policy action might have stronger effects on investment in an environment of poor credit quality and tight financial conditions for nonfinancial firms. However, the effectiveness of expansionary monetary policy does not seem to depend as much on firm financial conditions.

In the current context, given the high share of financially constrained firms, the results in the paper imply that the potency of the recent interest rate increases by the Federal Reserve might be high.

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Table 1: Differential Capital Response of Tightening Shocks for Constrained Firms to Tightening and Loosening Monetary Policy Shocks

	$Log(\text{ Capital })_{t+8} - Log(\text{ Capital })_{t-1}$			
	(1)	(2)	(3)	(4)
MP Shock	-1.221***			
	(0.140)			
MP Shock × Constraint	0.322***	0.273***	0.265***	0.228***
	(0.036)	(0.040)	(0.039)	(0.039)
MP Shock × Tightening	-1.933***			
	(0.298)			
MP Shock × Constraint × Tightening	-0.528***	-0.519***	-0.496***	-0.450***
	(0.061)	(0.067)	(0.066)	(0.066)
R-squared	0.341	0.377	0.374	0.388
N	242,653	245,261	242,653	242,653
Firm FE	✓	✓	✓	✓
Time FE		✓	✓	
Industry-Time FE				✓
Industry-Quarter FE	✓		✓	
p: β[MP Shock × Const.]+ β[MP Shock × Const.× Tight.]=0	.00001	.000002	.000004	.00001

This table displays the coefficient from the following estimated equation:

$$\Delta_9 Log(K)_{i,t+8} = \underbrace{\beta_1 MP\ Shock_t}_{\text{Aggregate MP loosening}} + \underbrace{\beta_2 MP\ Shock_{t*} Constraint_{i,t}}_{\text{MP loosening constrained}} + \underbrace{\beta_3 MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Aggregate Differential Effect of Tightening}}$$
$$+ \underbrace{\beta_4 Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Differential Effect of Tightening constrained}} + \mathbf{X}'\gamma + \epsilon_{i,t}$$

where $\Delta_9 Log(K)_{i,t+8}$ is the difference in log capital between 2 years after the shock and the quarter before the shock. $Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t$ is the interaction between the proxmity of default, based on the negative value of distance to default, $Constraint_{i,t}$, the Miranda-Agrippino and Ricco (2021) monetary policy shock $MP\ Shock_t$, and a dummy that is one if the shock is contractionary and zero if it is accommodative, $\mathbb{1}Tightening_t$,. $\mathbf{X}$ includes controls and fixed effects and vary by column. The p-value displays the p-value for a t-test for $\beta_4 + \beta_2 = 0$. Standard errors are in parentheses. Standard errors are clustered at the firm level. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 2: Differential Debt Response of Tightening Shocks for Constrained Firms to Tightening and Loosening Monetary Policy Shocks

	$Log(real_debt)_{t+8} - Log(real_debt)_{t-1}$			
	(1)	(2)	(3)	(4)
MP Shock	-3.304***			
	(0.376)			
MP Shock × Constraint	0.553***	0.448***	0.450***	0.419***
	(0.110)	(0.120)	(0.120)	(0.122)
MP Shock × Tightening	-0.226			
	(0.726)			
MP Shock × Constraint × Tightening	-0.585***	-0.502**	-0.470**	-0.438*
	(0.211)	(0.228)	(0.229)	(0.232)
R-squared	0.293	0.314	0.313	0.318
N	213,022	214,915	213,022	213,022
Firm FE	✓	✓	✓	✓
Time FE		✓	✓	
Industry-Time FE				✓
Industry-Quarter FE	✓		✓	
p: β[MP Shock × Const.]+ β[MP Shock × Const.× Tight.]=0	.84252	.75074	.90537	.91248

This table displays the coefficient from the following estimated equation:

$$\Delta_9 Log(Debt)_{i,t+8} = \underbrace{\beta_1 MP\ Shock_t}_{\text{Aggregate MP loosening}} + \underbrace{\beta_2 MP\ Shock_{t*} Constraint_{i,t}}_{\text{MP loosening constrained}} + \underbrace{\beta_3 MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Aggregate Differential Effect of Tightening}}$$
$$+ \underbrace{\beta_4 Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Differential Effect of Tightening constrained}} + \mathbf{X}'\gamma + \epsilon_{i,t}$$

where $\Delta_9 Log(Debt)_{i,t+8}$ is the difference in log debt between 2 years after the shock and the quarter before the shock. $Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t$ is the interaction between the proxmity of default, based on the negative value of distance to default, $Constraint_{i,t}$, the Miranda-Agrippino and Ricco (2021) monetary policy shock $MP\ Shock_t$, and a dummy that is one if the shock is contractionary and zero if it is accommodative, $\mathbb{1}Tightening_t$,. $\mathbf{X}$ includes controls and fixed effects and vary by column. The p-value displays the p-value for a t-test for $\beta_4 + \beta_2 = 0$. Standard errors are in parentheses. Standard errors are clustered at the firm level. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

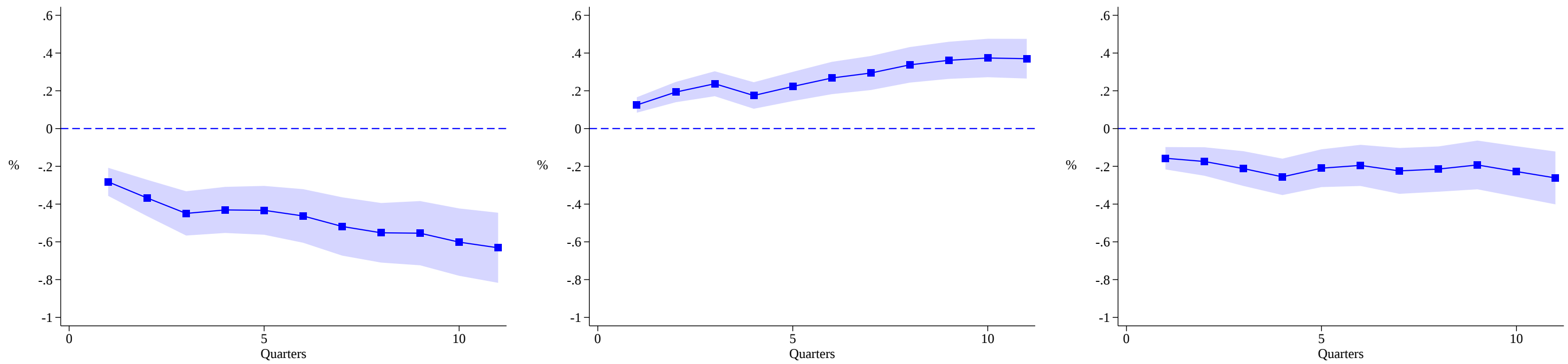
Table 3: Differential Employment Response of Tightening Shocks for Firms further away from Default

	Log(Employment)$_{t+8}$ − Log(Employment)$_{t-1}$			
	(1)	(2)	(3)	(4)
MP Shock	-1.007***			
	(0.096)			
MP Shock × Constraint	0.253***	0.163***	0.160***	0.141***
	(0.024)	(0.026)	(0.025)	(0.025)
MP Shock × Tightening	-0.867***			
	(0.216)			
MP Shock × Constraint × Tightening	-0.419***	-0.319***	-0.310***	-0.274***
	(0.043)	(0.047)	(0.047)	(0.047)
R-squared	0.363	0.404	0.403	0.413
N	233,270	235,790	233,270	233,267
Firm FE	✓	✓	✓	✓
Time FE		✓	✓	
Industry-Time FE				✓
Industry-Quarter FE	✓		✓	
p: β[MP Shock × Const.]+ β[MP Shock × Const.× Tight.]=0	.000012	.00002	.00004	.00036

This table displays the coefficient from the following estimated equation:

$$\Delta_9 Log(Emp)_{i,t+8} = \underbrace{\beta_1 MP\ Shock_t}_{\text{Aggregate MP loosening}} + \underbrace{\beta_2 MP\ Shock_{t*} Constraint_{i,t}}_{\text{MP loosening constrained}} + \underbrace{\beta_3 MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Aggregate Differential Effect of Tightening}}$$
$$+ \underbrace{\beta_4 Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Differential Effect of Tightening constrained}} + \mathbf{X}'\gamma + \epsilon_{i,t} \tag{30}$$

where $\Delta_9 Log(Emp)_{i,t+8}$ is the difference in log employment between 2 years after the shock and the quarter before the shock. $Constraint_{i,t} \times MP\ Shock_t * \mathbb{1}Tightening_t$ is the interaction between the proxmity of default, based on the negative value of distance to default, $Constraint_{i,t}$, the Miranda-Agrippino and Ricco (2021) monetary policy shock $MP\ Shock_t$, and a dummy that is one if the shock is contractionary and zero if it is accommodative, $\mathbb{1}Tightening_t$, $\mathbf{X}$ includes controls and fixed effects and vary by column. The p-value displays the p-value for a t-test for $\beta_4 + \beta_2 = 0$. Standard errors are in parentheses. Standard errors are clustered at the firm level. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

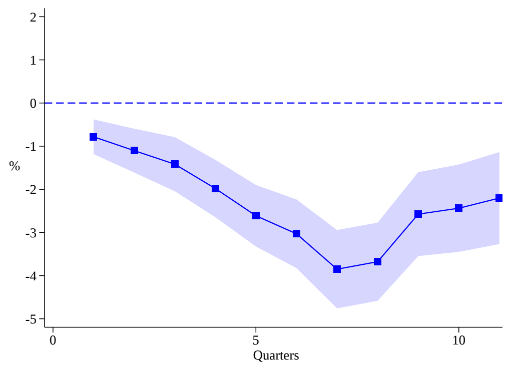


(a) Differential Effect of Constraint **(b) Effect of Constraint for Loosening** **(c) Effect of Constraint for Tightening**

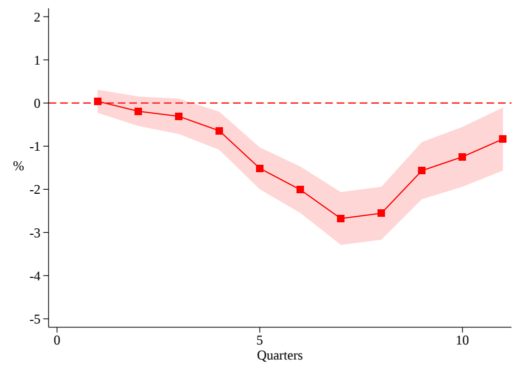
Figure 1: Local Projections: Differential Effects of Constraints to Tightening and Easing Shocks.

Notes: The charts display the coefficient estimate measuring the differential effect of constraints to monetary policy tightening or easing shock. Panel (a) shows the coefficient of the triple interaction, measuring the differential effect of constraints for tightening shocks relative to loosening shocks. Panel (b) plots the double interaction measuring the effect of constraints for easing shocks. Panel (c) plots the sum of the double and triple interaction measuring the effect of constraints for tightening shocks. The dependent variable is the difference between the log of total capital in period t+h and in period t-1. The monetary surprise in quarter t is calculated by adding up the monthly monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021). Shaded areas represent the 99% confidence intervals of the estimates.

Tightening Shocks

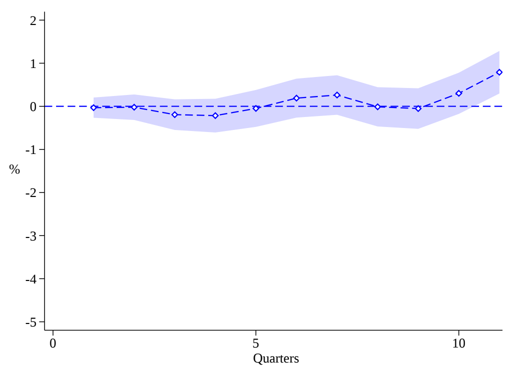


(a) Constrained Firms

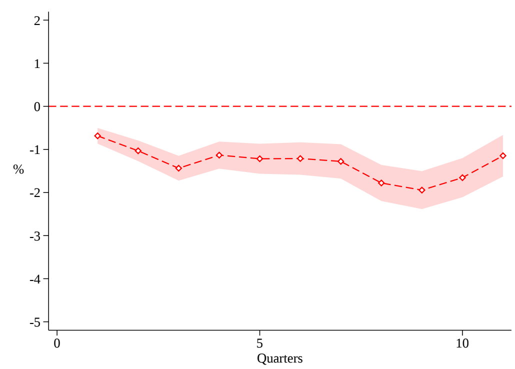


(b) Unconstrained Firms

Loosening Shocks



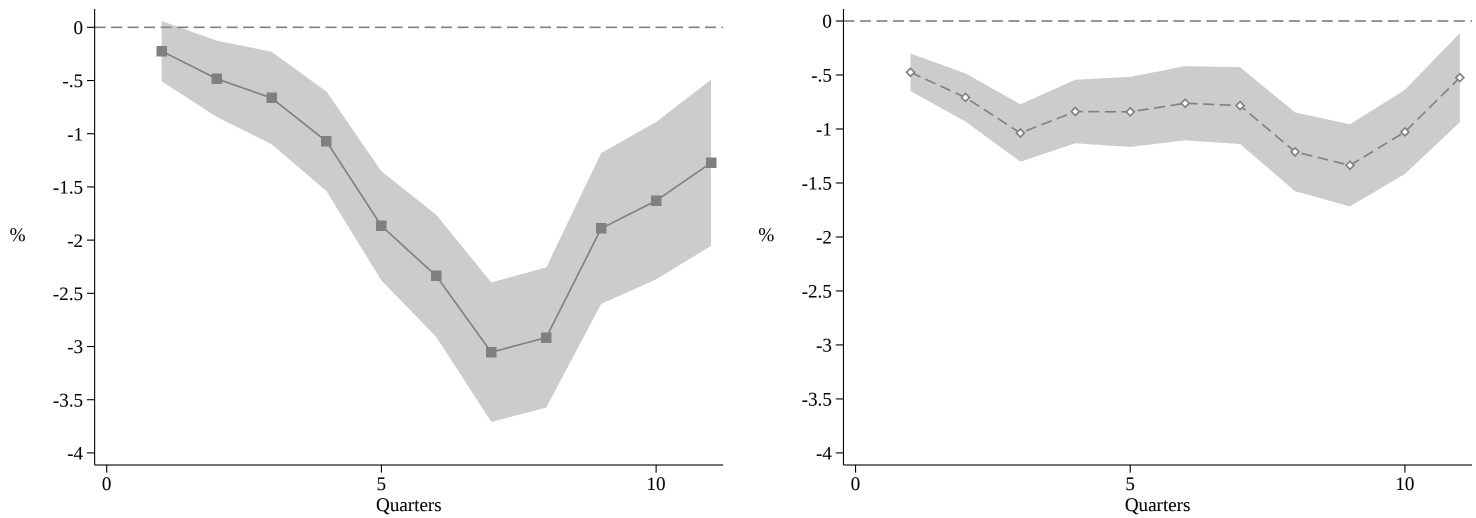
(c) Constrained Firms



(d) Unconstrained Firms

Figure 2: Local Projections: Response of Investment to Tightening and Easing Shocks by Constraint.

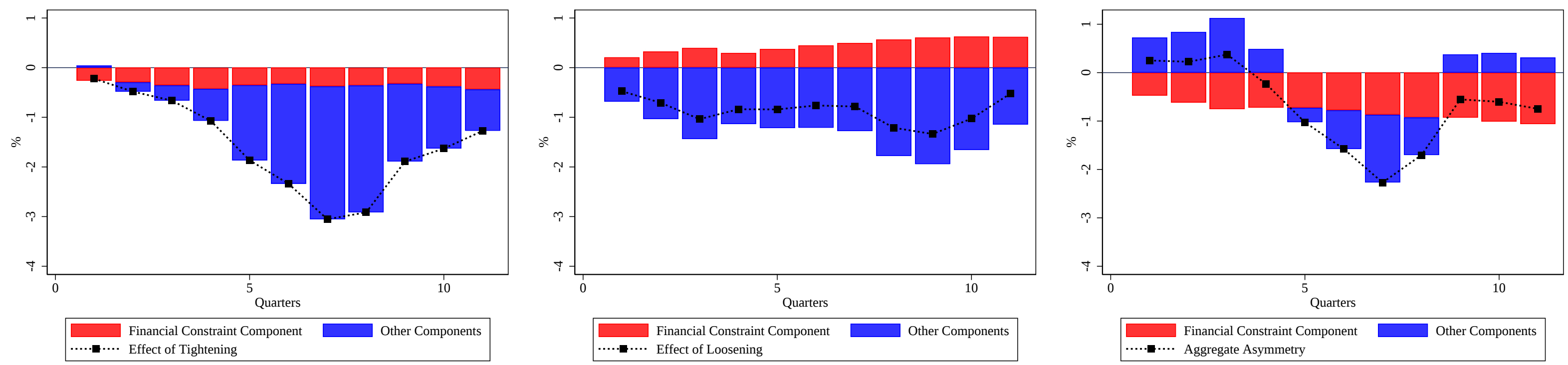
Notes: The charts display the estimate of the dynamic response of investment to a one standard deviation monetary policy tightening or easing shock, respectively. Constrained firms are those at the 75th percentile of the constraint, while unconstrained firms are those at the 25th percentile of the constraint. The upper panels show the effect of contractionary shocks while the lower panels report the effect of accommodative shocks. The dependent variable is the difference between the log of total capital in period *t+h* and in period *t-1*. The monetary surprise in quarter *t* is calculated by adding up the monthly monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021). Shaded areas represent the 99% confidence intervals of the estimates.



(a) Tightening Shocks **(b) Loosening Shocks**

Figure 3: Local Projections: Average Response of Investment to Tightening and Easing Shocks.

Notes: The charts display the estimate of the dynamic response of investment to a one standard deviation monetary policy tightening or easing shock, respectively. The left panel shows the effect of contractionary shocks while the right panel reports the effect of accommodative shocks. The dependent variable is the difference between the log of total capital in period $t+h$ and in period *t-1*. The monetary surprise in quarter t is calculated by adding up the monthly monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021). Shaded areas represent the 99% confidence intervals of the estimates.



(a) Tightening Shocks **(b) Easing Shocks** **(c) Asymmetry**

Figure 4: Local Projections: Decomposition Asymmetry.

Notes: The charts display the decomposition of the effect of financial constraints and other factors to monetary policy. The black line shows the tightening shock (a), easing (b), and the asymmetric average effect (c). The red bars show the contribution of financial constraints to the respective average effect. The blue bars show the contribution of other factors to the effects. The dependent variable is the difference between the log of total capital in period *t+h* and in period *t-1*. The monetary surprise in quarter t is calculated by adding up the monthly monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021). Shaded areas represent the 99% confidence intervals of the estimates.

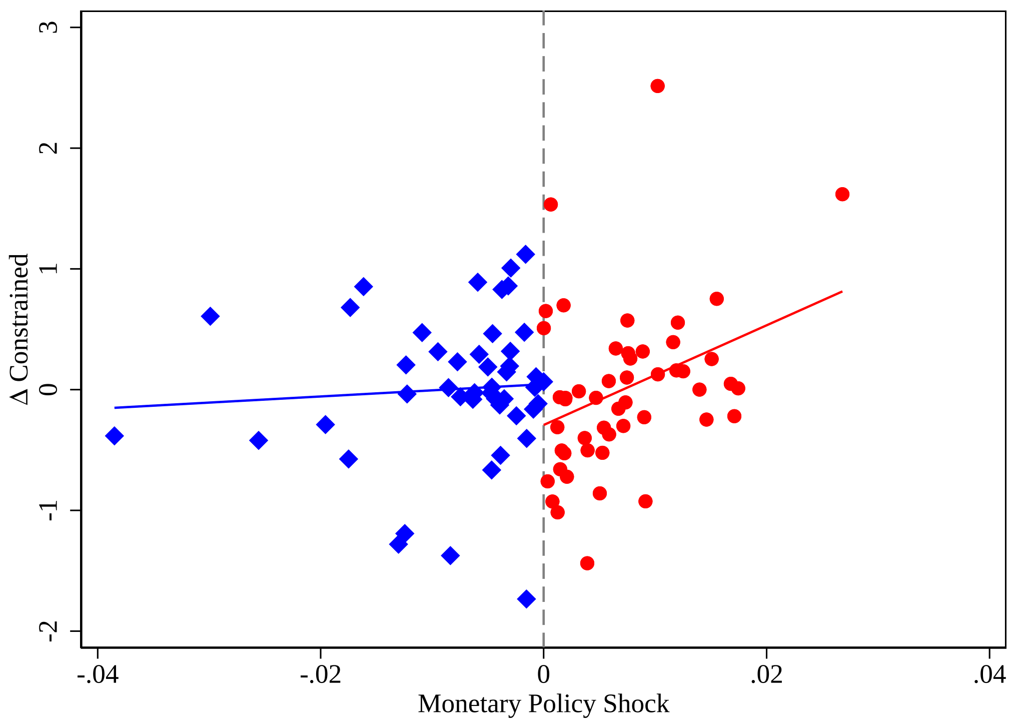


Figure 5: Response of Financial Constraints to Tightening and Easing Shocks.

Notes: The charts display the change in the financial constraint on the vertical axis and the monetary policy shock on the horizontal axis. Positive shocks reflect contractionary monetary policy shocks and negative shocks reflect accommodative monetary policy shocks. The monetary surprise in quarter t, is calculated by adding up the monthly monetary policy shocks obtained from Miranda-Agrippino and Ricco (2021).

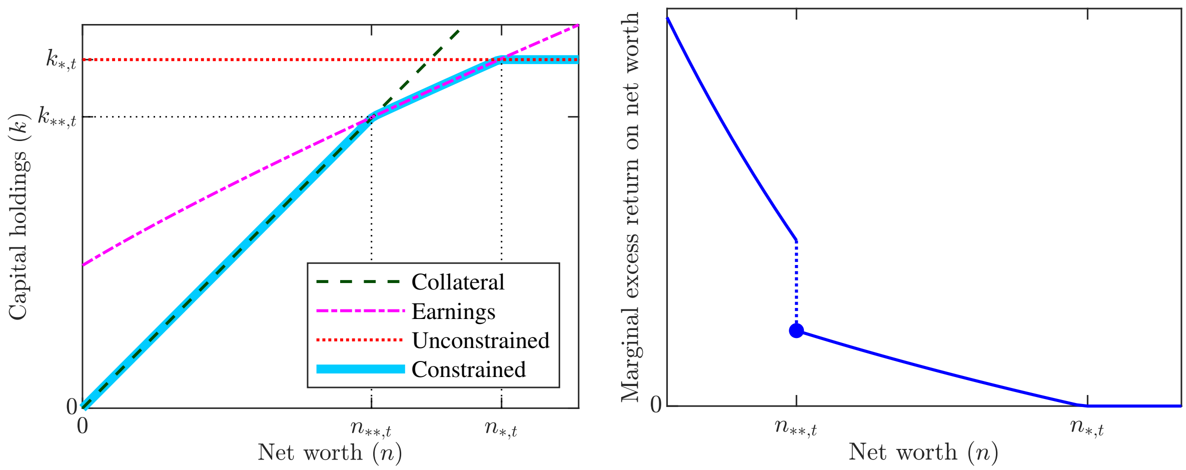


Figure 6: Holdings of physical capital & Marginal excess return on net worth.

Notes: Parameter values: $R = 1.02$, $\alpha = 0.5$, $\theta = 0.6$, $\lambda = 0.7$, $\gamma = 0.32$, $\varphi = 0.01$, $\beta = 0.5$.

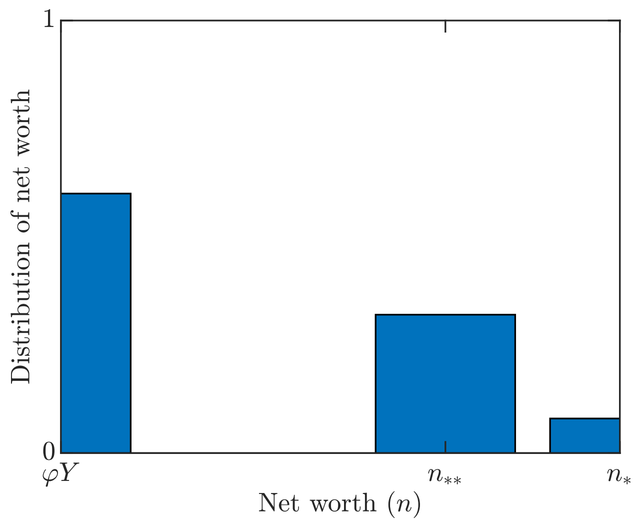


Figure 7: Aggregate distribution of net worth.

Notes: Parameter values: $R = 1.02$, $\alpha = 0.5$, $\theta = 0.6$, $\lambda = 0.7$, $\gamma = 0.32$, $\varphi = 0.01$, $\beta = 0.5$.

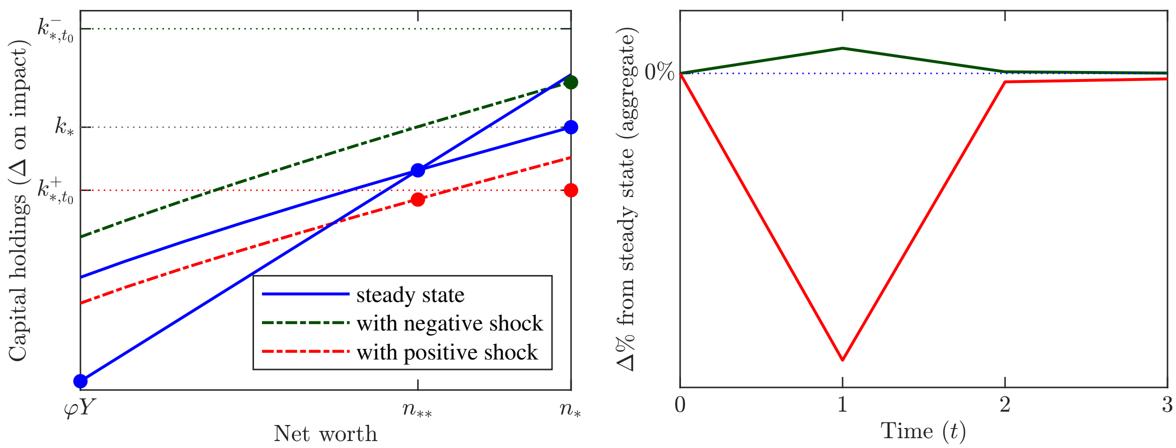


Figure 8: Impulse responses to shocks to the interest rate.

Notes: The left panel displays the responses to a negative and a positive shock on impact for each entrepreneur. The right panels display the aggregate impulse responses for each shock. Parameter values: $R = 1.02$, $\alpha = 0.5$, $\theta = 0.6$, $\lambda = 0.7$, $\gamma = 0.32$, $\varphi = 0.01$, $\beta = 0.5$. $|\varepsilon| = 0.4$.

Table 4: Effect of Number of Constraints on the Differential Investment Response of Tightening Shocks for Firms Further Away from Default

	$Log(Capital)_{t+8} - Log(Capital)_{t-1}$			
	(1)	(2)	(3)	(4)
	All Firms	Bottom Tercile # Constraints	Med Tercile # Constraints	Top Tercile # Constraints
MP Shock	1.155***	0.635	0.776*	2.217***
	(0.285)	(0.524)	(0.438)	(0.523)
MP Shock × Constraint	0.289***	0.146	0.298***	0.304***
	(0.056)	(0.105)	(0.085)	(0.103)
MP Shock × Tightening	-2.621***	-1.973**	-2.285***	-3.892***
	(0.421)	(0.795)	(0.646)	(0.749)
MP Shock × Constraint × Tightening	-0.425***	-0.288**	-0.342***	-0.481***
	(0.076)	(0.145)	(0.113)	(0.140)
R-squared	0.334	0.363	0.344	0.294
N	172,634	37,420	73,216	61,998
Firm FE	✓	✓	✓	✓
Time FE				
Industry-Time FE				
Industry-Quarter FE	✓	✓	✓	✓
p: β [Shock*Const.]+ β [Shock*Const.*Tight.]=0	.0001	.0269	.4044	.0063

This table displays the coefficient from the following estimated equation:

$$\Delta_9 Log(K)_{i,t+8} = \underbrace{\beta_1 MP\ Shock_t}_{\text{Aggregate MP loosening}} + \underbrace{\beta_2 MP\ Shock_{t*} Constraint_{i,t}}_{\text{MP loosening constrained}} + \underbrace{\beta_3 MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Aggregate Differential Effect of Tightening}} + \underbrace{\beta_4 Constraint_{i,t} * MP\ Shock_t * \mathbb{1}Tightening_t}_{\text{Differential Effect of Tightening constrained}} + \mathbf{X}'\gamma + \epsilon_{i,t} \quad (31)$$

where $\Delta_9 Log(K)_{i,t+8}$ is the difference in log capital between 2 years after the shock and the quarter before the shock. $Constraint_{i,t} \times MP\ Shock_t * \mathbb{1}Tightening_t$ is the interaction between the proxmity of default, based on the negative value of distance to default, $Constraint_{i,t}$, the Miranda-Agrippino and Ricco (2021) monetary policy shock $MP\ Shock_t$, and a dummy that is one if the shock is contractionary and zero if it is accommodative, $\mathbb{1}Tightening_t$, $\mathbf{X}$ includes controls and fixed effects and vary by column. The regression is run for separate subsamples: the entire sample in col. (1) and the bottom, middle, and top terciles in columns (2), (3), and (4), respectively. The p-value displays the p-value for a t-test for $\beta_4 + \beta_2 = 0$. Standard errors are in parentheses. Standard errors are clustered at the firm level. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.